Development of Wearable Computing, Advanced Visualization, and Distributed Data Tools for Mobile Task Support

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ABSTRACT

This paper presents an overview of SSC San Diego projects to develop novel information systems based on wearable computing, advanced visualization, and wireless technologies. User-centered design of these devices, to include proper principles of human perception and cognition, enables individuals to interact seamlessly with information and with other personnel regardless of their physical location. The results are better decision-making and shortened timelines for task completion.

INTRODUCTION

New approaches to on-the-job information support are being made possible by advances in wearable computing, hand-held information devices, and wireless communications technologies. Expanded data-storage capacity, innovative visual displays, and small lightweight packaging provide many choices for the design of systems that enhance information access, decision-making, and communication among sailors or Marines regardless of their location.

While commercial products can be assembled to accommodate a variety of purposes, an enterprise-level perspective is still required to realize their full potential. SSC San Diego has supported this need by integrating diverse commercial technologies, mapping them to user applications, adding design or functional improvements as appropriate, and conducting impartial performance testing of the resulting systems. SSC San Diego's goal is to ensure the smooth integration of commercial products into capable and robust military systems that support new operational capabilities.

ENABLING TECHNOLOGIES

Mobile information tools continue to emerge from industry at an accelerating rate. Critical technologies for enabling mobile support include improved computing resources, innovative information displays, interaction tools optimized for portability, a range of small imaging sensors, and a wireless communications infrastructure. These technologies can provide the user with responsive, easily accessible task and decision support at virtually any work location. The quantity and variety of these new products, however, only highlight the essential engineering tasks of system integration and testing to ensure that technology investments are ultimately realized as practical enhancements to naval capabilities. Although such tools may work well independently, it is their combined interaction that provides major advances in mission effectiveness.

Computing Resources

Computing and storage power for wearable or hand-held computers expands at roughly the same rate as desktop units, owing to the increased interest in these portable devices for an ever-widening range of industrial jobs. Typical commercial systems feature Pentium II CPUs in the 233-MHz

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class, with random access memory (RAM) resources of 160 MB and integrated hard-drive storage of 8 GB. Many vendors have already announced systems with greater power.

Information Displays

High-resolution color displays (e.g., 640 x 480 pixels), readable in both bright and dim light, are now available in hand-held and head-worn variants. While hand-held systems are most common, head-mounted displays (HMDs) support task performance in unique ways. In particular, HMD information is always available in the field of view so the user does not need to look away from the workspace. Some systems feature "see through" capability, where information is presented on a semitransparent surface or on the lenses of eyeglasses. If additional sensors are added to the system to track head position, displayed information can be synchronized, or registered, with the real-world scene, much like a pilot's head-up display (HUD). This approach is known as "augmented reality," and current applications include labeling and explanations of equipment parts, visualization of subassemblies that cannot be directly seen, animations of component operation, and sequential cueing of procedures as they are performed. SSC San Diego researchers have developed new display metaphors for effectively presenting information on HMDs—with special emphasis on augmented reality—and have conducted systematic user testing to establish the most appropriate allocation of information between hand-held and head-worn displays. In addition, SSC San Diego has generated inexpensive concepts for head tracking required to support practical augmented reality displays.

Interaction Tools

Miniaturized keyboards, keypads, and mouse tools are already familiar to users of portable computers, although stylus tools and speech recognition are becoming more common due to personal digital assistant (PDA) popularity and the growing need for hands-free computer interaction in offices. SSC San Diego has tested each of these technologies and has, additionally, developed gesture control methods (i.e., computer interaction using hand and finger movements with specially instrumented gloves) for interacting with information on HMDs.

Sensors and Imaging Tools

The utility of mobile information devices is clearly enhanced when they are equipped with sensors that capture data about the work environment (to document a task or to share visualization with others) or when they are equipped with sensors that extend human senses in hazardous situations. Video and still cameras are commonly used in industrial settings to support maintenance collaborations with remote technicians, and both military and civilian communities have employed thermal and low-light sensors during firefighting and surveillance tasks. SSC San Diego engineers are exploring the roles of such sensors in a variety of field, ship, and shore settings through user interviews and job analysis.

Information Sharing

Whether recording data on site, transmitting data to another site, or accessing remote data resources, essentially all naval jobs involve information sharing. Portable information tools on the commercial market typically offer some form of sharing through physical transfer (e.g., computer docking), or through radio, infrared, modem, or cell phone connectivity. Most recently, wireless local-area network (LAN) technologies—and Internet-based communications methods—have become a primary focus of fleet interest for distributed information exchange aboard ship. Internet-based communications are useful for linking networks of people and data sources with each other. SSC San Diego is actively involved with ship- and shore-based wireless LAN systems, and has designed innovative extensions to Internet communications protocols that support the unique demands of mobile, intermittent connectivity (such as lost or unreliable communications nodes, retransmission of unacknowledged data, etc.).

SSC SAN DIEGO DEVELOPMENT ROLE

There is no shortage of portable, yet potent information technologies to support mobile Marines and sailors. Operational effectiveness of new systems, however, must be preceded by a development process that starts with examination of user task and information needs, moves through informed selection and integration of component technologies, and concludes with field validation testing. Given that most technologies now originate from the commercial sector, execution of this process represents the essential "value added" contribution of SSC San Diego engineering. Two projects that illustrate this SSC San Diego development role in wearable computing technologies are the Advanced Interface for Tactical Security (AITS) and the Virtual Technical Data System (VRTDS).

Advanced Interface for Tactical Security (AITS)

The AITS project—an initial SSC San Diego effort in mobile computing and visualization—was intended to support field soldiers. Specifically, the Defense Threat Reduction Agency (DTRA) charged SSC San Diego with developing an intuitive information interface for U.S. Army security system operators (although units of all the military services perform similar missions). These personnel monitor sensors of diverse types are placed around the perimeter of a protected area. When sensors detect an intrusion, security operators must quickly orient themselves and interpret the nature of any threat. The AITS design effort began with observations and interviews of several security units, and proceeded based on documented user information needs.

AITS is based on a commercial wearable computer with both HMD and backup hand-held displays (Figure 1). SSC San Diego engineers extended this foundation with a commercial global positioning system (GPS) unit for location tracking, a compass and tilt sensor for head tracking, a wireless communication subsystem, and an instrumented glove for gesture control of display features. Head tracking permitted the development

FIGURE 1. Based on a commercial wearable computing system and augmented with SSC San Diego-developed software and display concepts, AITS is used for field surveillance and monitoring. With use of see-through display components and head-tracking technology, symbology can appear superimposed over the environment.

of three distinct display modes based on the operator's gaze:

1. When the operator looks up—a raw information display from whichever sensor initiated an alert.
2. When the operator looks down—a geo-referenced map presentation, synchronized to the user's location.
3. When the operator scans the horizon—discrete target cues and supporting information about the detected intrusion.

AITS provides a practical augmented reality interface for field use and permits security operators to monitor their sensor suite while on the move. Internet protocol extensions, described above, support data sharing by multiple security operators in real time, using the continuously updated map display. The AITS interface introduces a range of new display, interaction, and tracking capabilities at relatively low cost; SSC San Diego developers are currently testing user response to these design features.

Virtual Reality Technical Data System (VRTDS)

VRTDS was initiated as a component of the Network-centric Q-70 program under the sponsorship of the Space and Naval Warfare Systems Command (SPAWAR). VRTDS built upon a technical foundation established by AITS and is intended to support a variety of mobile shipboard tasks. The VRTDS design approach involves a selectable range of sensors, displays, computing resources, and interaction tools, all placed on a foundation of wireless communications technologies (Figure 2). VRTDS can present information in a variety of formats and incorporates augmented reality concepts for selected applications. Because VRTDS relies on proper selection and configuration of commercial components, the interface can be tailored in cost and capability, and can grow with new technologies. VRTDS emphasizes situation awareness and ease of operation for faster response and reduced training requirements.

FIGURE 2. The VRTDS employs a see-through display concept, with graphics and text superimposed over the environment, which can provide maintenance and troubleshooting information directly in the user's field of vision. VRTDS displays can be controlled with gestures, using a specially instrumented glove.

The VRTDS development process is characterized by early and frequent involvement of operational communities (e.g., tactical decision-makers, maintenance personnel, and technical experts) concerning design features and functions. VRTDS has given explicit priority to information display and decision support issues, with technology selection and integration used only to realize a required information need. Shipboard functions targeted for VRTDS support include maintenance, emergency response, telemedicine, and command and control.

Maintenance

The visualization tools for maintenance support typically provide for the electronic display of equipment diagrams and text material. More sophisticated methods, however, can furnish the technician with views of the inner assemblies of equipment before maintenance begins. Such tools can also present amplifying information about equipment without making a person stop and consult manuals. Portable computing systems with flexible commercial software can even be employed in place of current test equipment, i.e., "virtual test instruments," providing both the computer processing and the visual interface for a variety of troubleshooting functions now supported by special-purpose devices. When maintenance tasks are completed, these same portable tools can be used to document the actions performed, the parts used or ordered, and the results of the repair effort—information that can then be uploaded to remote databases to support quality-assurance measures, trend analyses, material resupply, and scheduling of future tasks. Finally, advanced visualization and computing tools can be used to deliver maintenance training and procedures practice in order to keep seldom-used or complex skills sharp while deployed.

Emergency Response

Current damage-control activities are still coordinated almost exclusively with verbal communications. Data visualization using portable sensors, personnel tracking, and wireless communications tools can, however, disseminate a large volume of status information accurately and quickly to team leaders and to the ship captain in order to enable more rapid selection and efficient deployment of response resources. Expanded use of such tracking technologies can support real-time location of all personnel deployed in ship spaces, as well as report on their condition and welfare (e.g., through physiological and environmental sensors), thus greatly reducing the time required to locate and account for ship crew members during emergencies.

Telemedicine

It is a relatively straightforward matter to extend the application of maintenance and emergency response features, described above, to the needs of telemedicine. A combination of special sensors (e.g., physiological monitors, thermal and conventional imaging cameras), virtual test equipment concepts (to process sensor signals), on-site data stores, and wireless data sharing provide a complete foundation for mobile medical personnel to gather and transmit casualty data from the encounter site, to confer with remote experts, and to record care procedures for patient processing.

Command and Control

Finally, VRTDS components are being examined as interfaces for Navy command and control applications. Such interfaces could provide tactical information to the warfare commander without the space and power requirements of current workstation displays. Furthermore, this information would be available regardless of where the commander was physically situated in the ship. Such a distributed computing and visualization capability could, for example, permit personnel to monitor and control ship systems, evaluate tactical displays, and control weapons entirely from a variety of locations. Control authority is, however, a central issue beyond the realm of technology support; this application is, therefore, only exploratory.

SUMMARY

Wearable computing, portable visualization tools, and distributed communications tools have already proven their value for many shipboard activities; mobile information support, wearable computing systems, and wireless communications have all been successfully tested both ashore and aboard ship with the help of SSC San Diego engineers. Current SSC San Diego efforts are focused on incorporating additional government and commercial technologies into these mobile information systems, developing a stable testing facility, and coordinating efforts with other agencies.

Military and engineering leaders should be prepared to expect powerful new tools from these technologies and should also be prepared to think boldly when formulating management schemes to use such capabilities. In whatever form such systems evolve, however, SSC San Diego will have an important role to play to ensure that the Fleet obtains maximum benefit from its investment.

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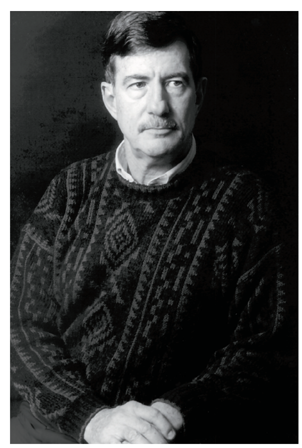

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Current Research: Augmented reality; wearable computing; operator alertness and performance measurement.